II.6 Small-Scale Low-Cost Solid Oxide Fuel Cell Power Systems

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Objective

- To develop a commercially viable 5-10 kWe solid oxide fuel cell power generation system that achieves a factory cost goal of $400 per kWe.

Approach

- Improve cell performance through new cell design and new materials.
- Lower operating temperature from 1000°C to 800°C.
- Eliminate internal fuel reformers through on-cell reformation.
- Develop low-cost high-volume manufacturing processes.
- Use low-cost module materials due to lower operating temperature.
- Simplify balance-of-plant (BOP) design by elimination of parts.

Accomplishments

- Fabricated high power density (HPD) seal-less planar cells. A new design that combines the seal-less feature and a flattened cathode with integral ribs was chosen. The ribs reduce the current path length by acting as bridges for current flow. This cell design, due to shorter current path, has lower cell resistance and hence higher power output than tubular cells.
- Demonstrated 30% higher power density for HPD cells compared to tubular cells.
- Demonstrated over 1000 hours voltage stability for HPD cells at 1000°C and 85% fuel utilization.
- Developed bundling technique for HPD cells. Bundles with up to 11 HPD cells were fabricated.
- Completed module design for a 5-kWe proof-of-concept system with HPD cells. Module design for the proof-of-concept unit was completed with identification and layout of components. Number and type of cells required to obtain the required power output were finalized.

Future Directions

- Optimize HPD cell design in terms of number of channels and dimensions.
- Develop cell materials for operation at 800°C.
- Improve cell performance through optimized cell design and new materials.
- Assemble and test proof-of-concept system.

Introduction

The objective of this project is to develop a standard high-performance, low-cost solid oxide fuel cell (SOFC) system that can be manufactured in high volume for application in a number of different end uses, including residential power generation and auxiliary power units (APUs) in commercial and military transportation applications. This project is a ten-year, three-phase project with prototype SOFC systems being tested at the end of every phase. Performance and cost improvements made during each phase will be incorporated in each prototype, and products based on each prototype will be made ready for market entry as they become available.

Approach

We have identified key technical issues that must be resolved to achieve low-cost commercial SOFC systems. We will focus on cost reductions and performance improvements to transform today's SOFC technology into one suitable for low-cost mass production of small systems for multi-market applications. The key advances identified are:

- Improved cell performance through design and materials innovations to double the power and thus reduced cost per kWe
- On-cell reformation of natural gas fuel to eliminate high-cost internal reformer components
- Sulfur-tolerant anodes to eliminate the fuel desulfurization system
- Use of low-cost insulation and containment vessels by lowering the system operating temperature
- High-efficiency (95%) power conditioning systems to improve overall system electrical efficiency
- Cost-effective fuel processing systems for operation of the standard SOFC module on alternate fuels

In addition to the key advances noted above, adoption of more automated mass production techniques for cell, module and BOP manufacturing will ensure overall SOFC system cost effectiveness.

Figure 1. Cylindrical and HPD Cells

Results

Prior to the start of the project, it was recognized that Siemens Westinghouse's seal-less tubular cell design would not be able to meet the cost and performance targets of the program. A need to develop a cell with higher power density and compact design was identified. A new design that combined the seal-less feature and a flattened cathode with integral ribs was chosen. This new design, referred to as high power density (HPD) SOFC, has a closed end similar to the tubular design. The ribs reduce the current path length by acting as bridges for current flow. The ribs also form air channels that eliminate the need for air feed tubes. This cell design, due to shorter current path, has lower cell resistance and hence higher power output than tubular cells.

Analytical modeling was initiated to optimize the number of ribs (channels) for maximum power and mechanical stability despite thermal stresses during operation. Based on initial results, HPD cell designs with five channels (HPD5) and 10 channels (HPD10) were selected for cell preparation to develop manufacturing processes and test electrical performance.

Several HPD5 and HPD10 cells were fabricated and tested for electrical performance. Figure 1 shows cylindrical and HPD cells. HPD5 cells showed over 30% higher power density compared to cylindrical cells, with the target being 100% more power density for the 10-year program. Figure 2 shows voltage versus current density comparison for cylindrical and HPD5 cells. Figure 3 shows voltage

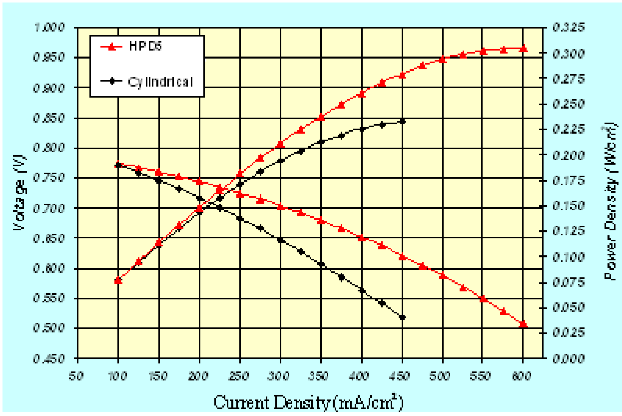

Figure 2. Voltage versus Current Density Comparison for Cylindrical and HPD Cells

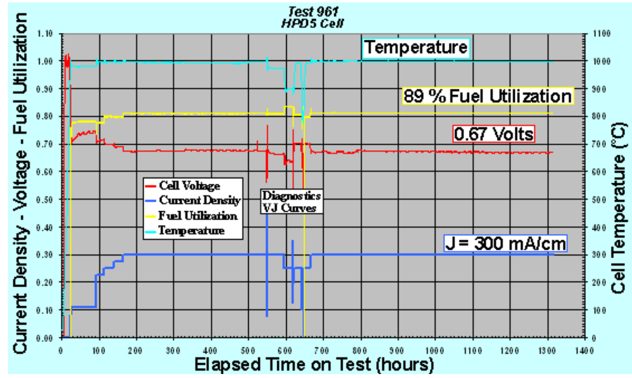

Figure 3. Voltage versus Time Plot for HPD5 Cell

stability of HPD5 cell over more than 1000 hours of operation.

Efforts were also directed towards the development of cell-to-cell connections to bundle cells. A bundle with 11 HPD5 cells was fabricated for demonstration purposes. Tensile tests to measure the mechanical viability and integrity of connections were conducted with acceptable results.

Conceptual design of a 5-kWe proof-of-concept system for residential applications was completed. Siemens Westinghouse worked closely with Fuel Cell Technologies (FCT), a partner in module and BOP development, on this task. The overall thrust of the task was to start from the existing residential prototype system design and develop concepts to simplify the system.

Conclusions

Fabrication processes for HPD cells were established, and electrical testing showed significant improvement in power density over cylindrical cells.

FY 2004 Publications/Presentations

1. S. D. Vora, SECA Program at Siemens Westinghouse, Presented at SECA Annual Workshop and Peer Review Meeting, May 11-13, 2004, Boston, MA